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MINERAL INFORMATION SERVICE

STATE OF CALIFORNIA — DIVISION OF MINES

VOLUME 14 NUMBER 1
JANUARY 1961

Geologic Sketch of the Northern Coast Ranges

---by Salem J. Rice

The northern Coast Ranges of California include some 13,000 square miles of rugged mountainous terrain that was sadly neglected in terms of geological exploration until recent years. Except for a few relatively small areas, the geology of this region remained unmapped until 1952. In that year the U. S. Geological Survey began a program of reconnaissance geological mapping of the drainage basins of the Eel, Mad, Trinity, Klamath, and Smith Rivers, an area of approximately 19,000 square miles. The field work was completed in 1955 as a cooperative project with the Division of Mines. The results of this work are now being published by the Division of Mines as Bulletin 179, *Geologic Reconnaissance of the Northern Coast Ranges and Klamath Mountains, California,* and also are being incorporated in the Santa Rosa, Ukiah, Redding, and Weed sheets of the new state geologic map currently being compiled by the Division. (The Ukiah sheet, covering the area enclosed by the 39th and 40th parallels between the coastline and the center of the Sacramento Valley, is the only one of these now available). Reconnaissance mapping yields only a rudimentary knowledge of the geology of an area, so much detailed geological work remains to be done in northwestern California. However, a sufficient start has been made to permit broad interpretations of the geological history of the region.

The Coast Ranges geomorphic province north of San Francisco Bay is bordered on the west by the Pacific Ocean, and on the east and northeast by the Sacramento Valley and the Klamath Mountains, respectively. A narrow neck of this province continues along the coast northward into Oregon. On topographic maps of California, the Klamath Mountains are seen to be continuous with the northern Coast Ranges, but the two regions are treated as separate geomorphic provinces because of significant lithologic and topographic differences. The northern Coast Ranges consist predominantly of unmetamorphosed sedimentary rocks that range in age from latest Late Jurassic to Tertiary, whereas the Klamath Mountains are largely carved out of older metasedimentary, metavolcanic, and plutonic igneous rocks.

The drainage system of the northern Coast Ranges has a trellis pattern, with all but one of the major streams that rise within the area flowing northwestward to the ocean. The one major exception is Russian River, which flows southeastward before it turns abruptly westward to cut its way through the mountains to the sea. This linear pattern contrasts sharply with the dendritic drainage pattern of the Klamath Mountains.

In general, the elevations of ridge crests within the northern Coast Ranges increase eastward from the ocean. Near the coast, elevations of 500 to 1500 feet are common, whereas the highest peaks that lie just west of the Sacramento Valley are 6500 to 8000 feet high.

Rocks and geologic history of the region

Probably the oldest rocks in the northern Coast Ranges are the metamorphic rocks that occur in two principal areas, one along the mountain front west of the Sacramento Valley and the other north and northeast of Eureka. These rocks are largely phyllite, slate, and mica schist, regionally metamorphosed sedimentary rocks that originally were shale and sandstone. Minor amounts of greenschist, representing metamorphosed volcanic rocks, and graphite schist derived from carbonaceous shales, are also present among these rocks. Neither the absolute age nor the relative age of these rocks is known with certainty, because no fossils have been found within them and their contacts with other rocks are either faulted or obscure, where examined to date. Thus they may represent metamorphosed sediments of the Franciscan formation (discussed later), of latest Jurassic and Cretaceous age, that comprises most of the northern Coast Ranges; but more likely they represent an

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MINERAL INFORMATION SERVICE is designed to inform the public on the geology and mineral resources of California and on the usefulness of minerals and rocks, and to serve as a news release on mineral discoveries, mining operations, markets, and statistics, and activities and publications of the Division. It is issued monthly by the California Division of Mines. Subscription price, January through December, is $1.00.

Other publications of the Division of Mines include the Annual Report of the State Mineralogist, the Bulletin and Special Report series, county reports, and maps. A list of the Division's available publications will be sent upon request. Communications to the Division of Mines, including orders for publications, should be addressed to the headquarters office.

older rock unit on which the Franciscan sediments were deposited. They are lithologically similar to metamorphic rocks of probable Late Jurassic age that occur in the western and southwestern parts of the Klamath Mountains.

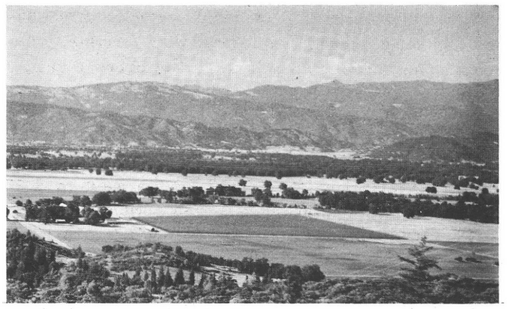
These rocks, particularly phyllite, graphite schist, and greenschist, are well exposed in sea cliffs and in Highway 101 roadcuts in the vicinity of Orick, northern Humboldt County, where they are thrust over rocks of the Franciscan formation. Another area of good exposure is along the road from Elk Creek through Alder Springs to the crest of the range in Glenn County, where they appear either to be gradational westward into, or overlain by, sediments of the Franciscan formation.

The bulk of the northern Coast Ranges is carved out of marine sedimentary rocks generally assigned to the Franciscan formation. This formation consists largely of graywacke, a type of sandstone made of unsorted angular mineral and rock grains that range in size from sand to clay. Most graywacke is gray to greenish gray on fresh surfaces, but is buff or brown when weathered. Because of its relatively high susceptibility to weathering, this rock does not tend to crop out prominently on natural slopes as do some of the less abundant rock types associated with it.

Other sedimentary rock types present in the Franciscan formation include black shale, radiolarian chert, conglomerate, and a minor amount of limestone. The chert is a colorful rock composed essentially of very fine-grained quartz, and crops out prominently because of its resistance to weathering. Most commonly it is found in sequences of thin beds, each an inch or so in thickness. Most Franciscan chert is brown, but some is green or white, and locally it is altered to red or yellow jasper. The unaltered chert normally contains abundant fossil remains of radiolaria, microscopic marine invertebrates that have siliceous skeletons, but unfortunately these have been of little value in dating the formation.

Intercalated with the Franciscan sedimentary rocks in many places are volcanic rocks that were emplaced largely as submarine lava flows. These are fine-grained rocks, and in most of them the ferromagnesian minerals have been altered to chlorite. The chlorite imparts a dull green color to the rocks and makes accurate identification of the original volcanic rock types difficult to determine in the field; as a result geologists usually refer to them as greenstone. However, laboratory study of specimens from numerous localities has revealed that most of these rocks were erupted as basalt. Chert and greenstone commonly occur together, the former having originated by precipitation of silica from sea water following the submarine eruptions. Greenstone, like chert, resists weathering and erosion more effectively than graywacke and shale, so it commonly occurs as bold, dark-colored outcrops on otherwise smooth, grassy slopes.

In many areas the Franciscan rocks are intruded by basic and ultrabasic plutonic igneous rocks. Notable among these is serpentine, one of the most widely distributed and distinctive rocks in northern California. Most travelers in this area are familiar with the characteristic pale green, slickensided serpentine exposed in many road cuts. The serpentine, derived by alteration of peridotite, is structurally incompetent compared with many of the rocks into which it is intruded, so most masses are highly sheared



View northeast across Round Valley, site of Covelo, Mendocino County. This is one of the few valleys of the northern Coast Ranges that contains deep alluvial fill. Distant ridges composed of rocks of the Franciscan formation. Leech Lake Mountain is on extreme right sky line.

BULLETIN 170 REPRINTED

The Division's popular bulletin *Geology of Southern California* has been reprinted and is now available. Originally issued in September 1955, the first printing was sold out by March of 1956. The second edition, which contains the same texts and maps as the first issue, plus a subject index, has been bound into two volumes.

A resume of the contents of the bound Volume I is as follows:

Chapter I. General Features: Investigations and problems of southern California geology; climate, vegetation and land use, and Indian occupation.

Chapter II. Geology of the Natural Provinces: Mojave Desert, Imperial Valley, Peninsular Range, Los Angeles Basin, Transverse Range, San Joaquin Valley, Techachapi Mts., Death Valley, Oceanside—San Diego, and offshore areas.

Chapter III. Historical Geology: Formations and faunas of Paleozoic, Mesozoic, marine Cenozoic ages, fossil foraminifera, Cenozoic land life, and Tertiary basins.

Chapter IV. Structural Features: Faulting in Southern California, seismicity, structure of Providence Mountains and turtlebacks in Death Valley.

Chapter V. Geomorphology: Physiographic features of faulting, geomorphic processes in the desert, beach and nearshore processes, Pleistocene glaciation and lakes, marine terraces, Cima Dome, and Imperial depression.

Chapter VI. Hydrology: The hydrology of the Los Angeles region, Mojave Desert, and Ventura County.

Chapter VII. Mineralogy and Petrology: Minerals in Southern California, metamorphic and igneous rocks of the Mojave Desert and western San Gabriel Mts., metamorphism in Southern California and at Crestmore, Southern California batholith, Miocene volcanic rocks and pegmatites in Southern California.

Chapter VIII. Mineral Deposits and Mineral Industry: Saline minerals, rare-earth deposits at Mountain Pass; tungsten, base metals and iron deposits, gold and silver in Mojave Desert, and marketing of nonmetallic commodities.

Chapter IX. Oil and Gas: Oil and gas production, history of oil exploration, origin, migration, and trapping of oil in Southern California and in San Joaquin Valley.

Chapter X. Engineering Aspects of Geology: Earthquakes and earthquake damage in Southern California, building site problems in Los Angeles, and subsidence of the Wilmington oil field.

Volume II is a cloth covered box which contains the Geologic Guides and Map Sheets. The five Geologic Guides provide road logs, maps and photographs for field trips to the (1) Western Mojave Desert and Death Valley regions, (2) Ventura basin, (3) Los Angeles basin, (4) southwestern portion of Los Angeles basin, and (5) northern part of the Peninsular Range province.

Unforeseen increases in cost of printing and binding the new volumes will make it necessary to charge *$13.00 plus 52¢ tax, postpaid, beginning February 1, 1961.* All orders received before this date will continue to be filled at the pre-publication price, $12.00.

It is expected that separates of all parts of the bulletin will eventually be available. At present, the following sections are ready, and may be purchased for the price quoted (to which, California residents please add 4 percent sales tax): Index ($1.00); Chapters 1, 3, 5, 6, 7, 8, 9, 10 ($1.00 each); Geologic guides 1, 3, 4, 5 (50¢ each); Preface (no charge).

Wood-burning steam tractor at Furnace Creek Ranch, Death Valley, used in an unsuccessful attempt to replace the famous 20-mule teams in the transportation of borax. From Bulletin 170, Geologic Guide No. 1.

Index to Volume 13

The numbers separated by colons refer to volume: number: page, in that order; for instance, Assessment work, deferment of, given as 13: 10: 8, appears in volume 13 (1960), number 10 (October issue), on page 8.

along the margins and many are also sheared internally by mountain-building forces. Unaltered peridotite, a dense, pale green rock composed of olivine and enstatite, is rare in the northern Coast Ranges except for one large mass at Red Mountain and adjacent Little Red Mountain in northwestern Mendocino County.

At a few localities in the Coast Ranges small masses of hornblende gabbro were intruded in close association with serpentine, and dikes or small masses of diabase are also present in places.

Among the most interesting and anomalous rock types within the Franciscan formation are the predominantly blue metamorphic rocks commonly called glaucophane schists. Although widely distributed in the Coast Ranges, individual outcrop areas of these rocks are typically small. Their usual contrast and anomalous contacts with adjacent unmetamorphosed rocks and their unusual mineralogy have stimulated widespread interest and study, but a reasonable explanation of their origin has not yet been found. The term glaucophane schist is loosely used in reference to them, for the assemblage of rocks grouped under this name includes metamorphic rocks of diverse mineral composition and texture. In many places they are massive. Glaucophane is so commonly present, and when predominant gives the rocks such striking colors of indigo blue to blue black, that the entire group of rocks is named for this mineral. The common occurrence of other minerals such as green actinolite, pyroxene, and chlorite, red garnet, and light-colored quartz, albite, lawsonite, and mica, in various combinations, produces rocks of widely variable color and texture. Most of them are highly resistant to weathering, so they ordinarily crop out prominently and accumulate as boulders and pebbles in streams.

The nature of the Franciscan rocks indicates much regarding the environment of deposition. The unsorted character and angular nature of the clastic grains of the graywacke indicates very rapid and turbulent deposition into a rapidly sinking submarine trough. Occasional quiesence is indicated by the relatively rare accumulations of shale, and sporadic submarine volcanism by the widely distributed accumulations of greenstone and chert.

Nevertheless, despite its widespread distribution this formation is one of the most controversial geological units in California, a state noted for its complex geology. Neither the base nor the top of the Franciscan has been definitely recognized in the field, so its contact relationships and thickness can only be conjectured. It is generally accepted that the formation must be at least 25,000 feet thick, and it may be considerably thicker. Until recently, few significant fossils had been found in rocks assigned to the Franciscan in northern California, but now a number of localities have yielded fossils that range in age from Late Jurassic to early Late Cretaceous.

Flanking the Coast Ranges along the western margin of the Sacramento Valley is a sequence of well-bedded, fossiliferous sedimentary rocks that have had considerable influence on concepts regarding the age of the Franciscan. These are the Knoxville formation, of latest Late Jurassic age, and the overlying Paskenta and Horsetown formations of Early Cretaceous age, as well as some Late Cretaceous strata. This entire sequence, largely conformable, consists principally of dark gray silty shale with numerous thin beds of sandstone and some conglomerate beds. The oldest of these formations, the Knoxville, abuts against the major north-south fault that is considered the boundary between the Great Valley and Coast Ranges geomorphic provinces in this region. Over much of its length this fault is indicated by a long, narrow belt of highly sheared serpentine, and it separates schist and phyllite to the west from unmetamorphosed Knoxville shale to the east. The base of the Knoxville is not exposed along the fault, and the Knoxville and Cretaceous beds dip steeply to the east. The easterly dip of these sedimentary rocks away from the mountains has led to the concept that they once projected on over the Coast Ranges to the west, covering both the metamorphic rocks and Franciscan formation, and have subsequently been largely eroded away from the mountainous area. Thus the Franciscan was considered to be older than the Knoxville. Certainly the largely massive Franciscan rocks are different in appearance from the well-bedded sediments of the Knoxville and Cretaceous formations of the Sacramento Valley sequence, but the similarity of the ages of the rocks of the two provinces is not compatible with the concept of superposition of one over the other.

Recent work by Irwin and Bailey (see references) has yielded a probable explanation for these confusing relationships. They present evidence that the sediments of the Franciscan formation were deposited contemporaneously with the Sacramento Valley sequence. The differences in the appearances of the rocks of the two sections are held to have been caused by different mechanisms of deposition within the north-south trough (geosyncline) in which the sediments accumulated. Accordingly, the well-bedded sediments of the Sacramento Valley sequence were deposited along the uniformly subsiding eastern margin of the geosyncline. Contemporaneously, the rapidly sinking central portion of the great trough, lying to the west, accumulated similar debris, but it was carried in by massive submarine landslides and turbulent currents

originating along the break in submarine slope and was so thoroughly mixed that it was deposited essentially without bedding. Also, the central and tectonically active portion of the geosyncline, approximately represented by the present outcrop area of the Franciscan formation, received sporadic volcanic eruptions that resulted in local accumulations of greenstone and chert.

By latest Cretaceous or earliest Tertiary time the great trough in which the Franciscan rocks accumulated was nearly filled, and orogenic forces were initiated that created a mountainous area from the thick pile of sediments deposited in the sea. Uplift was accompanied by compressive forces that resulted in northwest-trending folds and faults in the Franciscan. The Cenozoic history of the region is largely one of erosion of these rocks after they were raised above sea level, although there was periodic marine flooding of locally depressed embayments and seaways.

Narrow seaways still existed in Paleocene and Eocene times, for marine sedimentary rocks of these ages are found southeast of Clear Lake and in the Covelo area. These rocks are predominantly light-colored sandstone, with minor amounts of shale and conglomerate, and are not significantly different from Cretaceous rocks with which they are associated.

No sedimentary rocks of Oligocene age have been found in the northern Coast Ranges, so it is probable that the region was above sea level during this interval. Fossil plants found in nonmarine sediments in the Klamath Mountains and Sierra Nevada indicate that a moist subtropical climate prevailed here during Eocene and Oligocene times, tapering off to a temperate climate by mid-Miocene time. The rapid weathering and erosion resulting from these conditions reduced much or all of northwestern California to a land of low relief. Remnants of this erosion surface, commonly referred to as the Klamath peneplain, are particularly well preserved in the concordant, flat-crested ridges of the Klamath Mountains east of Crescent City. It is probable that some high flat-crested ridges in the Coast Ranges, such as Red Mountain in northern Mendocino County, are also remnants of this surface.

In late Miocene time orogenic forces became active toward creating the northern Coast Ranges as we know them. Beginning about this time, the lower Eel River valley area was depressed below sea level, forming an enbayment that accumulated a thick prism of sediments during the last half of Cenozoic time. These sedimentary rocks, called the Wildcat group, are particularly well exposed along the Eel River near Scotia and along the county road south of Ferndale.

Bluffs composed of Late Pliocene sediments at Agate Beach, Patrick's Point State Park, Humboldt County. Note angular unconformity. These sediments are largely uncemented sand and gravel, and are the source of pebbles of agate, jasper, jade, and other lapidary materials found on the beach.

They have been described in considerable detail by B.A. Ogle in Division of Mines Bulletin 164, *Geology of the Eel River Valley Area, Humboldt County, California.*

Other narrow embayments penetrated inland from the northern coastline during this interval while the old erosion surface was being warped into folds trending northwest. Small areas of late Miocene or Pliocene sedimentary rocks occur along or near the coast in the vicinity of Petrolia, along the Bear River (just north of Cape Mendocino), along the Mad River east of Arcata, in the Patrick's Point-Big Lagoon area, at Gold Bluffs (northwest of Orick), and in the vicinity of Crescent City. Relatively small outcrop areas of marine Miocene rocks near Covelo and marine Pliocene sediments near Garberville have been preserved by downfaulting into the older rocks, and indicate that one or more of the coastal embayments extended inland to the southeast for considerable distances.

To the south, minor marine encroachment during Pliocene time is indicated by the presence of thin remnants of the Merced formation resting on Franciscan rocks east of Stewarts Point and in the Sebastopol-Tomales area of southwestern Sonoma and north-Marin Counties.

The most notable Pliocene event in the southern part of the province was the advent of extensive

Quadrangle Geologic Mapping

Back, William, 1957, Geology and ground-water features of the Smith River plain, Del Norte County, California: U.S. Geol. Survey Water-Supply Paper 1254.

Brice, J.S., 1953, Geology of the Lower Lake quadrangle, California: California Div. Mines Bull. 166.

Evenson, R.E., 1959, Geology and ground-water features of the Eureka area, Humboldt County, California: U.S. Geol. Survey Water-Supply Paper 1470.

Gealy, W.K., 1951, Geology of the Healdsburg quadrangle, California: California Div. Mines Bull. 161. (Includes "Mineralogy of the California glaucophane schists", by George Switzer.)

Jennings, C.W., and Strand, R.G., (compilers), 1960, Geologic map of California, Olaf P. Jenkins edition, Ukiah sheet, scale 1:250,000, California Div. Mines.

Manning, G.A., and Ogle, B.A., 1950, Geology of the Blue Lake quadrangle, California: California Div. Mines Bull. 148.

Ogle, B.A., 1953, Geology of the Eel River Valley area, Humboldt County, California: California Div. Mines Bull. 164.

Travis, R.B., 1952, Geology of the Sebastopol quadrangle, California: California Div. Mines Bull. 162.

Weaver, C.E., 1949, Geology and mineral deposits of an area north of San Francisco Bay, California: California Div. Mines Bull. 149. (Vacaville, Antioch, Mount Vaca, Carquinez, Mare Island, Sonoma, Santa Rosa, Petaluma, and Point Reyes quadrangles.)

BAY AREA GEOLOGIC ROAD GUIDES AVAILABLE

In 1955 the Division of Mines prepared mimeographed geologic guides for two field trips in conjunction with the meeting in Berkeley of the Cordilleran Section of the Geological Society of America. One of the trips was concerned with the geology of the Sonoma-Petaluma area, and the other with the stratigraphy of the Oakland-Mount Diablo area. The guide for each consisted of a small-scale geologic map (approximately 1 inch equals 4 miles), a road log discussing the geology along the route, and a bibliography.

We still have about 50 of these sets available for 25¢ a set. Each set consists of a guide for each trip, totaling 10 pages of text and two maps, stapled together in a manila folder.

View northwest across Clear Lake and Mount Konocti. Clear Lake Highlands, a resort community, is in the foreground. Mount Konocti is a volcano of late Pleistocene age. Sulfur Bank mercury mine is the small white area on the extreme right. Ridges to right of lake and in the distance are composed largely of Franciscan graywacke and greenstone. Borax Lake, the small lake within the peninsula to right of center, is dammed by an obsidian flow on the southeast side. This is the site of the first discovery of borax in California. *Photo by Aero Photographers, Sausalito, California.*

RECENT REPORTS BY U.S.G.S.

The following reports were placed on open file in Room 232, Appraisers Bldg., San Francisco, by the U. S. Geological Survey during 1960. Although they cannot be purchased, they may be consulted at that office.

Landslides in the San Francisco South quadrangle, California, by M.G. Bonilla, 44 pp., 10 figs., 1 table; *Selected logs of borings on the east side of San Francisco Bay, California,* by Mary Alice Weaver and Dorothy H. Radbruch; *Geologic map of the Lane Mountain quadrangle,* by T.H. McCulloh; *Use of ground-water reservoirs for storage of surface water in the San Joaquin Valley, California,* by G.H. Davis, B.E. Lofgren, and Seymour Mack.

Two maps issued during 1960 may be purchased over-the-counter at the above address, or ordered from the U.S. Geological Survey, Washington 25, D.C., or Federal Center, Denver, Colorado: *Geologic map of the United States,* by G.W. Stose and O.A. Ljungstedt, scale 1:2,500,000 (a re-issue of the 1933 map with color changes, in four sheets – NE, SE, NW, SW), at $1.50 per sheet, or $6.00 for the set; *Mount Whitney quadrangle,* 15', scale 1:62,500 (with the new Independence, Mt. Pinchot, and Lone Pine 15' quadrangles, covers the old 30' Mt. Whitney sheet), price 30¢.

are easily detected. Yet details of folding and amounts of offset by faulting are extremely difficult to determine because of the lack of distinctive widespread lithologic horizons and the paucity of fossils.

Mineral resources

The northern Coast Ranges are not as rich in known commercial mineral resources as most other geomorphic provinces in California, but a wide variety of commodities has been produced and the potential for new discoveries is certainly not exhausted. Indeed, the advent of geologic map coverage should stimulate the search for new deposits within the province. During the early history of California this region received little attention because of the lack of rich gold deposits. Some placer gold has been found in a few relatively insignificant deposits, most or all derived from the adjacent Klamath Mountains, but no lode deposits are known.

Among the metals that have been produced in substantial amounts are mercury, manganese, chromium, and copper. Mercury production has been largely limited to many mines in the area south and east of of Clear Lake in Lake, Sonoma, Napa, Yolo, and Colusa counties. The mercury deposits are mostly in silica-carbonate rock, a rock derived by hydrothermal replacement of serpentine by silica and carbonate minerals.

Manganese deposits are widely distributed in the region, the mineralization being associated with chert of the Franciscan formation. Most of these deposits are small, but a few large ones have been found.

Chromite, limited in its primary occurrences to peridotite and serpentine, has been mined in most of the counties containing these rocks.

Copper production has come largely from the Island Mountain mine, in southwestern Trinity County. Here a massive sulfide orebody, associated with rocks of the Franciscan formation, yielded some 9,000,000 pounds of copper along with significant amounts of silver and gold. A number of other copper prospects are known in the Coast Ranges, but only a few of them have yielded small production.

A recently discovered occurrence of nickeliferous laterite at Red Mountain and Little Red Mountain, northern Mendocino County, was explored in 1958 and 1959.

Nonmetallic mineral commodities that have been produced commercially from the northern Coast Ranges include asbestos, clay, limestone, magnesite, perlite, sand and gravel, and expansible shale. Some of these, particularly sand and gravel, shale, and perlite, occur in large deposits that should become increasingly important to the construction industry of California.

Most of the mineral fuels have been found in places within the region, but only natural gas has been produced in significant quantities. As is the case with California as a whole, the fuels are largely found associated with marine sedimentary rocks of Tertiary age.

One of the most interesting recent developments is the utilization of natural steam at The Geysers, Sonoma County. Here super-heated steam, produced from wells a few hundred feet deep, is being used to generate electrical power, the first such development in North America.

A summary of the mineral deposits of the northern Coast Ranges and Klamath Mountains is presented in Bulletin 179, along with maps showing distribution of deposits of the various commodities. More specific information about most individual deposits is available in other Division of Mines publications.

BIBLIOGRAPHY

General References

Anderson, C.A., 1936, Volcanic history of the Clear Lake area, California: Geol. Soc. America Bull., vol. 47, no. 5, pp. 629-664.

Bailey, E.H., and Irwin, W.P., 1959, K-feldspar content of the Jurassic and Cretaceous graywackes of northern Coast Ranges and Sacramento Valley, California: Am. Assoc. Petroleum Geologists Bull., vol. 43, no. 12, pp. 2797-2809.

Davis, E.F., 1918, The Franciscan sandstone: California Univ., Dept. Geol. Sci. Bull., vol. 11, pp. 1-44.

Davis, E.F., 1918, Radiolarian cherts of the Franciscan group: California Univ., Dept. Geol. Sci. Bull., vol. 11, pp. 235-432.

Irwin, W.P., 1957, Franciscan group in Coast Ranges and its equivalents in Sacramento Valley, California: Am. Assoc. Petroleum Geologists Bull., vol. 41, no. 10, pp. 2284-2297.

Irwin, W.P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California: California Div. Mines Bull. 179.

Taliaferro, N.L., 1943, Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 2, pp. 109-219.

volcanism in the Sonoma Mountains area, east of Santa Rosa valley. Lava flows and volcanic ash deposits, collectively known as the Sonoma volcanics, were ejected from numerous fissures and piled up in places to depths of several thousand feet. By early Pleistocene time, activity waned south of Mount St. Helena as the volcanism gradually shifted northward to the vicinity of Clear Lake, where it continued until latest Pleistocene or Recent time. The principal type of lava ejected was andesite, but basalt, dacite, and rhyolite are also represented among the many flows in the region. Mount Konocti, on the south shore of Clear Lake, is the only volcano of significant size resulting from this activity. The abundant hot springs of the Clear Lake resort area are a residual effect of the recent volcanism there.

As minor warping and faulting progressed in the northern Coast Ranges during Pliocene and early Pleistocene time, small interior basins formed in several areas and were partially filled with nonmarine detritus. One of these, in eastern Lake County, accumulated up to about 2000 feet of sediments, largely sand and gravel, at about the same time as the volcanic activity in the Sonoma Mountains area. These sediments are called the Cache formation, and are well exposed along Highway 20 east of Clear Lake. Three other small basins that apparently originated in Late Pliocene or Early Pleistocene time, Ukiah Valley, Little Lake Valley (at Willits), and Round Valley, are now filled with thick deposits of clay, sand, and gravel.

Approximately in middle Pleistocene time, most or all of the area of the northern Coast Ranges was subjected to regional uplift. Evidence of this is found principally along the coast, where Pleistocene sediments and terraces have been elevated. For example, Eureka is built on marine terrace sediments of Pleistocene age, and Highway 1 follows elevated terraces along much of its route along the coast. By comparing the elevations of these features with present sea level, it becomes apparent that Pleistocene uplift was not constant from place to place. Terraces and deposits in some areas have been elevated several hundred feet, in others a few tens of feet. Indeed, the mouth of Russian River and the lagoons north of of Eureka are drowned stream canyons, indicating lower sea levels in the recent past than at present. These features were probably caused, at least in part, by lowering of sea level by some 200 feet during Pleistocene time when ice accumulated on the northern continents. Thus geomorphic interpretations are complicated by two processes: one being the fluctuations of sea level during the ice age, and the other being the tectonic activity along the whole coastal area.

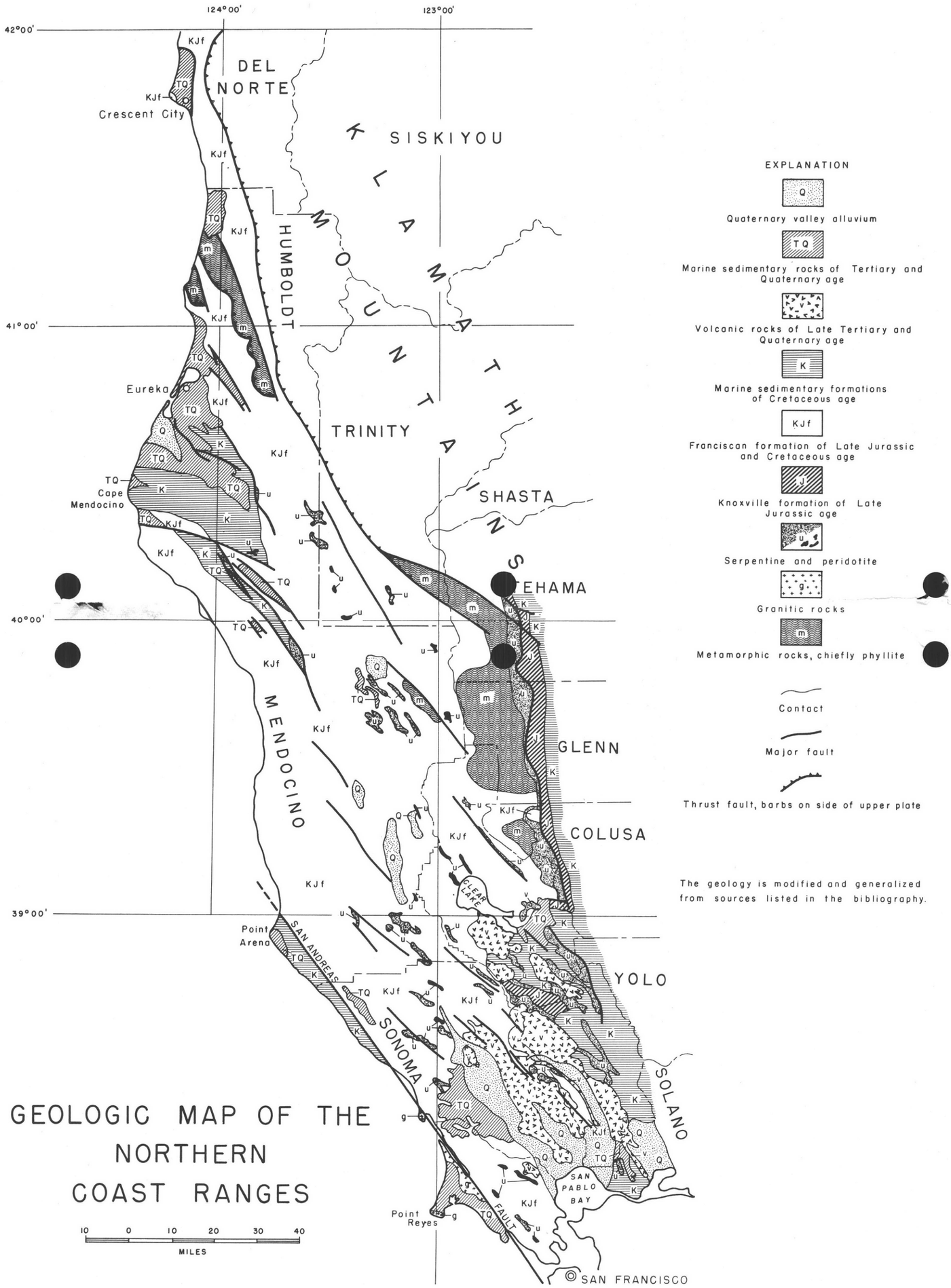
View north along the Pleistocene marine terrace followed by Highway 1 near the mouth of the Navarro River, Mendocino County. This wave-cut terrace is about 200 feet above sea level. Older and higher terrace, visible on right sky line, is about 700 feet above sea level.

Geologic structure

The geology of the province is not known in sufficient detail to yield a clear understanding of its geologic structure. However, certain major structural features are clearly demonstrated by the mapping that has been done, among them the following:

1. All of the formations that are older than Pliocene have been folded and faulted. Particularly, the rocks of the Franciscan formation have been highly deformed and sheared along broad northwest-trending zones. Highway 101 approximately follows the most noteworthy of these zones; the long valleys and abundant landslides along its route being topographic expressions of the shearing and deformation.
2. The northern Coast Ranges are separated from the Klamath Mountains by a reverse or thrust fault.
3. The northern Coast Ranges are separated from the Great Valley by a fault, probably a normal fault.
4. The San Andreas rift traverses the southwestern coastal area of the province, continuing under the sea northwest of Point Arena.
5. The Gorda submarine escarpment, a major structural feature of the earth's crust, intersects the coastline in the vicinity of Cape Mendocino.

Structural studies within the Franciscan formation are difficult, to say the least. Traces of bedding may be seen in many areas, and faults and shear zones



GEOLOGIC MAP OF THE NORTHERN COAST RANGES